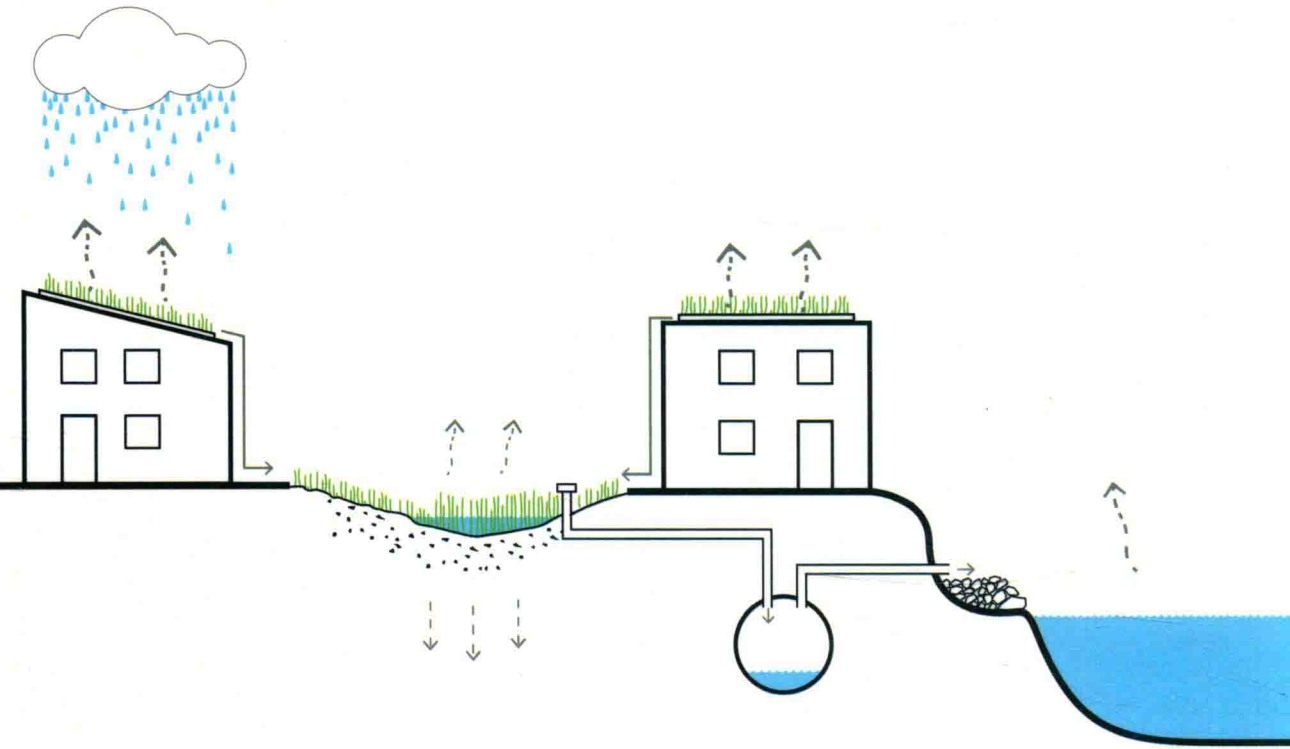


Daniel Roehr and
Elizabeth Fassman-Beck



Living Roofs

in Integrated Urban Water Systems

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Living Roofs in Integrated Urban Water Systems

With the infrastructure to manage stormwater threats in cities becoming increasingly expensive to build or repair, the design community needs to look at alternative approaches. Living roofs present an opportunity to complement ground-level stormwater control measures, contributing to a holistic, integrated urban water management system.

This book offers tools to plan and design living roofs, in the context of effectively mitigating stormwater. Quantitative tools for engineering calculations and qualitative discussion of potential influences and interactions of the design team and assembly elements are addressed.

Daniel Roehr is an Associate Professor at the University of British Columbia School of Architecture and Landscape Architecture in Vancouver, Canada, a registered landscape architect in Vancouver and Berlin and a horticulturalist. Roehr has designed and researched living roofs for over 20 years with his most significant work being the ground-breaking water sensitive living roof design of the DaimlerChrysler project Potsdamer Platz in Berlin, Germany.

Elizabeth Fassman-Beck is an Associate Professor in the Department of Civil, Environmental, and Ocean Engineering at Stevens Institute of Technology in Hoboken, New Jersey, USA. She has worked extensively with regulatory agencies to develop evidence-based technical and practical design criteria for stormwater control measures. Her former research team in Auckland, New Zealand developed the first living roof design guidance prioritizing stormwater management.

Figures

1.1	Living roofs: a tool and system component	5
1.2	Living roof: a tool with multiple benefits	6
1.3	Typical living roof assembly	9
2.1	Example rainfall frequency spectrum for Minneapolis, Minnesota	23
2.2	States of soil moisture	26
2.3	Runoff volume and peak flow frequency spectrum for a living roof in Auckland with average growing media depth of 60mm	29
2.4	Plants decrease ET rate exponentially as the amount of water stored in the growing medium depletes	35
3.1	The planning table: tasks and communications links	53
3.2	The construction management table: tasks and communication links	55
3.3	Facility management planner's table: tasks and communication links	56
3.4	Protrusions and perforations	60
3.5	Warm and inverted roof cross-sections	61
3.6	Well grown versus poorly grown vegetation depends on design objectives and comprehensive planning	63
3.7	Rational Formula volumetric runoff coefficients determined from 15 living roof studies from the United States, Canada, Italy, UK and New Zealand	82
3.8	Conceptual representation of a living roof in SWMM 5.1	84
4.1	For stormwater retention, depth of a finished living roof is determined according to the size of the design storm and the growing media's PAW	107
4.2	Wet versus dry climate-tolerant plants	112
4.3	Sloped roofs at VanDusen Entrance Building, Vancouver and Hypar Pavilion Lincoln Centre, New York	118
4.4	Roof slope scenarios	119
4.5	Roof pitch (slope) unit conversions	120
4.6	Typical parapet	122
4.7	Viewing experience: flat versus pitched roof	122

4.8	Viewing experience: effects of height	122
4.9	Drainage channel	123
4.10	Drainage pipe dimension and position on façade	123
4.11	Hybrid system	126
4.12	Irrigation system options	127
4.13	Ideal roof	128
4.14	Maintenance access	130
4.15	Patio paving	132
4.16	Footings for architectural elements	133
4.17	Floating grate	133
5.1	VanDusen Botanical Gardens and Visitor Centre: a holistic stormwater management system diagram	142
5.2	Port of Portland headquarters system diagram	146
5.3	Mirabella and The South Waterfront District stormwater runoff system diagram	150
5.4	Potsdamer Platz stormwater runoff system diagram	154
5.5	Tryon Creek stormwater runoff system diagram	158

Tables

2.1	Empirical evidence from one intensive and four extensive living roofs: median (standard deviation) large storm per event retention	30
3.1	List of professionals and their main area of engagement in a living roof project	49
3.2	Living roof building element checklist for new roofs and retrofits	62
3.3	Runoff curve number according to Köppen Geiger climate zone	78
3.4	Literature values: peak runoff coefficients for living roofs	81
3.5	Summary of selected hydrologic models commonly applied for living roofs	87
4.1	Specifications to consider in growing medium development	99
4.2	Water-holding capacities of growing media reported in the literature	102
4.3	Basic design checklist	135
5.1	Project specifications: VanDusen Botanical Garden Visitor Centre	142
5.2	Project specifications: Port of Portland	146
5.3	Project specifications: The South Waterfront District	150
5.4	Project specifications: Potsdamer Platz	154
5.5	Project specifications: Headwater at Tryon Creek	157

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Robyn Simcock, Ph.D., *Contributing Author (Chp 3 & 4).* Simcock is an ecologist and soil scientist, works with storm water engineers to develop novel growth media and plant systems using natural ecosystem processes to mitigate impacts of highly modified urban environments. Robyn is a graduate in Horticultural Science (BHortSci First Class; Massey University, New Zealand) with a Ph.D. in mine restoration. She has worked for Landcare Research, the crown-owned research institute charged with driving innovation to protect and enhance New Zealand's terrestrial environment, for nearly 20 years. Since 2006 Robyn has worked collaboratively with regulatory authorities to deliver research and technical guidance (with Dr. Elizabeth Fassman-Beck) on living roofs and Green Infrastructure, including New Zealand's unique biota and rich volcano-generated resources.

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Daniel extends his fondest gratitude to his parents, who have always supported his career, despite years abroad for the greater part of his life.

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Abbreviations

INSTITUTIONS

ASCE	American Society of Civil Engineers
ASTM	American Society of Testing Materials
EPA	(USA) Environmental Protection Agency
FLL	Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau
FSC	Forest Stewardship Council
LEED	Leadership in Energy and Environmental Design

TERMS

ARI	Annual Recurrence Interval
BMP	Best Management Practice
CAM	Crassulacean Acid Metabolism
CN	Curve Number
CSO	Combined Sewer Overflow
ESD	Environmental Site Design
ET	Evapotranspiration
GI	Green Infrastructure
GSI	Green Stormwater Infrastructure
LID	Low Impact Development
LWA	Light-Weight Aggregate
PAW	Plant Available Water
SBS	Styrene Butadiene Styrene
SCM	Stormwater Control Measure
SMEF	Soil Moisture Extraction Function
SUDS	Sustainable Urban Drainage System
TSS	Total Suspended Solids
WSUD	Water Sensitive Urban Design

Contents

<i>List of figures</i>	vii
<i>List of tables</i>	ix
<i>Notes on contributors</i>	x
<i>Acknowledgments</i>	xii
<i>List of abbreviations</i>	xiv
1 Introduction	1
1.1 Why worry about water? Water as a driver for living roof implementation	1
1.2 Opportunities for living roofs	5
1.3 Classifications	8
1.4 Functional components	9
1.5 Three fundamental concepts	12
1.6 Book methodology	13
2 The role of living roofs in holistic storm water management systems	19
2.1 The urban water balance in municipal regulations	20
2.2 An engineer's perspective on quantitative stormwater design objectives	21
2.3 Technical challenges imposed by municipal stormwater codes	23
2.4 How a living roof "works" to control stormwater runoff	24
2.5 Stormwater performance expectations	27
2.6 Evapotranspiration	34
2.7 Hydrologic models	38
2.8 Discussion	41
3 Planning considerations	48
3.1 Planning process	48
3.2 The step-by-step process for planning	50
3.3 Key elements for collaborative planning	57
3.4 Plants	62
3.5 Stormwater calculations	71
4 Integrating stormwater performance and architectural design	94
4.1 Growing medium	94

4.2	Water retention techniques	108
4.3	Plant selection	109
4.4	General planting design guidelines	115
4.5	Drainage layers	116
4.6	Experiential aspects	118
4.7	Extent of roof greening	124
4.8	Irrigation	125
4.9	Accessibility	127
4.10	Provision for monitoring	131
4.11	Design for social function without compromising stormwater control	132
4.12	Lighting	134
4.13	Design checklist	134
5	Case studies	141
5.1	Introduction to small and large scale design scenarios	141
5.2	Case studies	142
6	Outlook	162
	Glossary	165
	Index	173

Chapter 1: Introduction

1.1 WHY WORRY ABOUT WATER? WATER AS A DRIVER FOR LIVING ROOF IMPLEMENTATION

Water is crucial for life on earth. It is our most precious resource. In many parts of the world, water scarcity causes immense hardship for human, animal and plant life. The extent of these areas is steadily increasing (International Water Management Institute 2000; Rijsberman 2005; UN Water, Food and Agriculture Organization of the United Nations 2007). The quality of water has been degrading rapidly since the Industrial Revolution, a situation which has been accelerated by the immense increase in population over the last 40 years (Albiac 2009; Carr and Neary 2009; Nienhuis and Leuven 2001). In the Western world, concerns over water extend beyond basic infrastructure to now address the preservation of ecosystems and ecosystem services. With increasing urgency, urban development professionals including architects, landscape architects, engineers and planners are researching and implementing various methods to recycle, store and reuse water, improve its quality, and protect or restore the natural resource base from which it is extracted (Margulis and Chaouni 2011; Planning Institute Australia 2003).

What we do with water use (how much) and its management (quality, where it ends up, and how fast it travels) at a local level always impacts a larger system, which in turn, feeds back to the availability and quality of water in our cities. Of the many forms that water takes, this book is concerned with urban stormwater runoff. It examines the role and design of living roofs to mitigate runoff's environmental and infrastructure impacts, while creating productive urban spaces. Living roofs have to be seen from two sides: the pragmatic/technical side from an engineer's point of view alongside the environmental, social and/or aesthetic/experiential side from a designer's point of view. Designers try to create a human experience resulting in a higher quality of life but this cannot happen without the engineer's objective to protect water resources for creating and sustaining life.

Urban stormwater runoff poses a suite of receiving water and infrastructure impacts that threaten public health and welfare as much as ecosystem services, but also offers an opportunity of a resource to be captured for beneficial uses.

The historic focus of an urban drainage system was to expediently remove or dispose of runoff so as not to disrupt urban activities, damage structures or threaten public safety. Expedient removal is no longer the only goal or cost. In some cases, it is not the goal at all. Almost every aspect of the hydrologic cycle (water's distribution and flux in a watershed) is modified by urban development. In a natural forested condition, 10–20 mm of precipitation may be intercepted by the vegetated canopy and infiltrated (soaked) into the ground before stormwater runoff is generated at the surface. In an urbanized condition, runoff may be generated from as little as 2 mm of rain. Thus, in urban settings, flows are generated almost every time it rains, and pollutants are transported to receiving waters such as streams, rivers, lakes, estuaries, bays and harbors. Increased flow rates, runoff volumes and occurrence of runoff along with how quickly runoff is initiated contribute to channel erosion and instability, which degrades both physical and biological habitat structure by a process known as hydromodification (US EPA 1993). Studies show that marked alteration of channel flow processes is associated with declining ecological health, or degradation of the physical channel attributes required for normal ecological functioning (Gippel 2001). Across the United States, receiving water quality has largely been considered “degraded” for decades; pollutants carried by urban runoff are largely discharged without treatment. Altogether, hydromodification and pollutant loadings compromise aquatic habitat, infrastructure and property almost every time it rains.

Reducing or avoiding impacts from “everyday” rainfall events is increasingly incorporated into policy, but has not historically been the focus. Since 2001, US state and municipal agencies in Portland, Philadelphia, Seattle, Atlanta, Chicago, New York, Pittsburgh, Washington State, California, Maryland, Vermont and Virginia have introduced policies and related design requirements. Significant legislation enacted in 2007, Section 438 of the USA Energy Independence and Security Act, requires extensive on-site runoff control from “everyday” events for federal facilities undergoing new or redevelopment. Living roof technology is perfectly suited to mitigate these sorts of storm events.

In many older cities, “everyday” stormwater impacts to receiving environments are exacerbated or even superseded by combined sewer overflows (CSOs). Combined sewers are intended to carry sanitary sewerage and stormwater runoff through the same pipes to a municipal wastewater treatment plant. In many major cities around the world, urban infill and densification now generate flows well exceeding the carrying capacity of the combined sewer network. By design, overflow points discharge untreated runoff and sanitary sewerage into receiving environments when the capacity of the sewer is exceeded during wet weather (e.g., rain or snowmelt). While the intention is to prevent overloading the municipal wastewater treatment facility, and causing even greater volumes of untreated wastewater discharge, the impacts to local receiving environments can be devastating. In Brooklyn, NY, modeling predicts CSO events to occur almost every time it rains, without intervention (City of New York 2008). In New Jersey, the state with the highest population density in the United States, as little as 5 mm of rain

regularly causes CSOs (NY/NJ Baykeeper.org 2013). Philadelphia is served by 164 permitted CSO discharge points, serving 48 percent of the city (PWD 2011). While larger storms cause the greatest volume of CSO, smaller storms create the greatest number of CSO events. In many areas of the United States, these sorts of discharges are in violation of the 1972 Clean Water Act and its amendments (including the 1994 Combined Sewer Overflow Control Policy) and/or the Wet Weather Water Quality Act of 2000. In the Pacific Northwest, CSOs and runoff contaminants including the elevated temperature of untreated stormwater runoff threaten salmonids protected by the 1973 Endangered Species Act. Environmental regulation and impending lawsuits and/or fines, exacerbated by shifting public awareness and opinion, is causing municipalities and water utilities to invest significant resources in reducing the frequency and volume of CSOs, and restoring degraded waterways.

Upgrading buried infrastructure is increasingly found to be uneconomical and impractical compared to surface-level action. Rigid grey infrastructure (pipes, pumps, tanks and centralized treatment plants) lacks resilience. Alternatively, small and large cities around the world are developing or are already implementing green infrastructure (GI) solutions for stormwater management. Although many definitions of GI have been proposed, a useful compilation is “Natural and engineered ecological systems which integrate with the built environment to provide the widest range of ecological, community, and infrastructure services” (greeningofcities.org 2012). The term green stormwater infrastructure (GSI) is specifically used to identify approaches for runoff management.

Decisions defending GI and GSI adoption cite economics, inability to achieve technical objectives using grey infrastructure, and multi-functionality over and above provision of ecosystem services, particularly with respect to human health and social capital. Across the world, the two largest municipal investments in GSI were recently introduced in Philadelphia and New York City, specifically to address CSO control and receiving water quality improvement. After a comprehensive alternatives analysis, the Philadelphia Water Department (PWD) determined that traditional grey infrastructure would be “cost prohibitive while also missing the restoration mark.” Instead, the PWD is investing US\$1.2 billion (2009 net present value) in GSI and in excess of US\$3 billion in GI over 25 years “towards greening the city as a means to provide specific benefits ... while meeting ecological restoration goals” (PWD 2011: 3). Implementing GI across New York City is projected to eliminate \$1.4 billion and defer \$2 billion from the municipal government’s budget for state-mandated grey infrastructure projects (City of New York 2012).

On a smaller scale, site or block-level initiatives are often instigated by municipalities in response to neighborhood complaints. Many successful stories and/or pilot projects are emerging from Seattle, Portland, Lancaster (Pennsylvania), New York City and Washington, DC where GI solutions for stormwater are integrated into street or intersection redevelopment to improve traffic and pedestrian safety. Addressing runoff problems at – or close to – the source with GI eases the